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Guptill, E. W.; Terroux, F. R.; Watson, W. H.; National Research Council Canada. Radio Branch

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Publisher’s version / Version de l'éditeur:
https://doi.org/10.4224/40003989

PRB; no. PRB-93, 1943-02-24

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NATIONAL RESEARCH COUNCIL OF CANADA
RADIO BRANCH

REPORT ON VEB ANTENNA FOR MEW

OTTAWA
FEBRUARY 1943

NATIONAL RESEARCH COUNCIL OF CANADA
RADIO BRANCH

REPORT ON VEB ANTENNA FOR MEW

CONTENTS

REPORT ON VEB ANTENNA FOR MEW

This report has two aims. First we have an estimate of the factors which at present appear to us to enter most critically in the design problem. Secondly we have included a summary of the work to date since our last formal report, in which we recorded data on L-shaped coupling probes by means of which the dipoles can be made to present a non-reactive load to the waveguide feeding the array. We indicated then our intention to investigate methods for increasing the equivalent shunt resistance presented by a dipole and its probe to the guide, so as to allow $\lambda_g/2$ spacing of the dipoles. This exploratory work in the course of which much experimental information has been recorded, will not be reported in detail here. We hope that the summary of the lines of investigation will be adequate as a guide to the detailed information which can be supplied on request.

I. SUMMARY OF EXPERIMENTAL INVESTIGATION:

In the earlier part of the work, the standing wave method was used to measure the equivalent shunt impedance of the radiating elements. As it was desired to have the resistance as high as possible and the reactance as nearly as possible zero, we were forced ultimately to give up that technique for the determination of reactance and to use a phase meter instead. (See 4 below).

1. L-Shaped Probes

a. The equivalent circuit of the dipole + feeder probe in the guide regarded as a transmission line shown in Figure 1(a) is given in Figure 1(b).

Z_α = impedance due to the dipole + that part of the probe outside the guide.

Z_β = capacitive reactance due to the vertical probe BC inside the guide.

Z_γ = the inductive reactance due to the horizontal part AB of the probe.

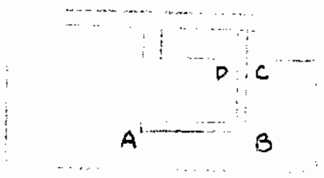

Fig. 1(a)

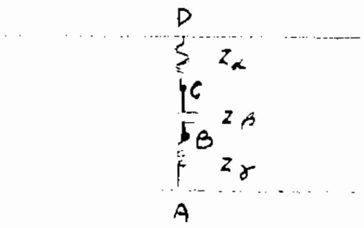

Fig. 1 (b)

We have tested this picture by terminating the guide in three different ways and measuring the equivalent impedance. By means of a plunger, AD was (i) short-circuited and (ii) open circuited and (iii) a

[illegible]

matched termination was used. The results showed that there is no ~~sine~~ element required in the equivalent line.

b. Provided that the probe AB is not too close to DC (Figure 1(a)) it is possible to determine $Z_\beta + Z_\gamma$ by supporting an L of size ABC by means of a thin polystyrene disc inserted in the hole in the top of the guide, and to predict the resulting shunt impedance of different dipole-probe combinations. Once antennas of very small reactance have been found and the reactance of ABC has been annulled by proper adjustment of its size under conditions where the resistance is negligible, it is possible to obtain a good reactance balance for the combination dipole + probe.

2. Reduction in Pillar Height as a mean~~a~~s of increasing shunt resistance

Measurements of equivalent X and R have been obtained with various pillar heights down to 1.5 mm, for different lengths of dipole. X is a function of both pillar height and length of dipole and at low pillar heights great precision is required to secure a low reactance. One is led to the conclusion that, on this ground alone, this method of increasing equivalent shunt resistance is not a suitable one. This investigation was carried through in considerable detail.

3. Other Shapes of Probes

The shape shown in Figure 2(a) was tried with the idea that the voltages in the two vertical parts of the probe would oppose each other thus increasing the resistance, while the horizontal part would be kept away from the hole in the top of the guide thus reducing the mutual coupling between the dipole and the horizontal probe in the guide. Actually there was found greater shunting of the guide. The equivalent circuit for this probe is shown in Figure 3 in which the condensers C^1 and C'' represent the shunting effect of the vertical portion AA'.

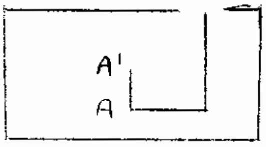

Fig. 2(a)

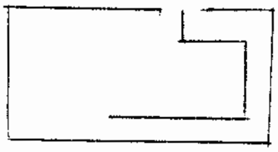

Fig. 2(b)

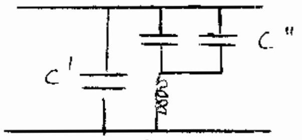

Fig. 3

Since mechanical considerations do not allow great reduction in the diameter of the dipole, the only method left to us was to place the vertical probe in a weaker field, hence a probe of the shape shown in Figure 2(b) was tried. This did increase the resistance considerably but reactance balance was not easy.

4. Reactance Measurement when the shunt impedance has a large resistance component

At this stage it became essential to seek a new method of reactance measurement. An exploring antenna was fixed outside the guide at about a wavelength from the dipole and parallel to it. The energy picked up was fed through a coaxial line (which could be accurately varied in length) to the rhumbatron-mixer of the phase meter already described by us. The signal used for comparison was taken from the maximum in the standing wave pattern in the guide between the shunt being measured and the oscillator. Complete tests have convinced us that the method is reliable; the interference with the guide-dipole system at both points of coupling is small. On the other hand, the full sensitivity of the detector is required for measurements of phase angle to the nearest 5 degrees, when the source is a #810 klystron matched to the guide.

5. Feed through the side of the guide

In order to bring the coupling probe to a position of weak electric field in the guide and yet retain 4 cm. dipoles with their centres in a straight line parallel to the guide, it was decided to feed from a hole in the side of the guide as shown in Figure 4. With a dipole of the type M.I.T. Radiation Lab. Drawing No. X1197 of 8-14-42, (fed through coaxial line), we have observed an equivalent shunt impedance of as high as 30 times the guide impedance. As AB is increased in length the guide is more heavily shunted and likewise if B is moved towards the centre of the guide.

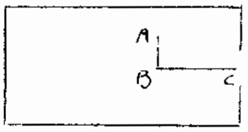

Fig. 4

The phase of excitation can be reversed by inverting AB.

6. Radiation Patterns of single end-fed dipoles excited from the guide

These patterns have been measured both for the desired and unwanted polarisations. With 4 cm. dipoles fed 1.7 cm. from the centre, and of pillar height less than 1 cm. the exposed piece of feeder probe is more effective as a radiator than the dipole itself, and even at greater pillar heights the field component polarised perpendicular to the dipole and to the surface of the guide is sufficiently strong to present a very serious difficulty to be overcome in feeding an array of these dipoles, for as we have already pointed out the dipoles should be excited from the inside of the guide only. The coaxial line supported dipole does not suffer from this disability but mechanically it is regarded as unsatisfactory because polystyrene supports are used. We believe that the split type dipole (British or M.I.T. patterns) will be found to suffer from excessive ~~in the~~ unwanted polarisation. We have just completed a series of measurements in which were varied, the positions of the feed-point, antenna length and pillar height of the "end-fed" dipoles, and have concluded that these dipoles are unsuitable as radiating elements in a long array. A minimum of radiation in the unwanted polarisation relative to the desired polarisation was observed as the feed point was displaced to the centre but this minimum was still too large. We have therefore to design a new type of radiating element. The two following proposals have been considered: (i) coaxial line fed dipoles, the central conductor being stub-supported, the T-join being "hidden" by means of a reflecting sheet and (ii) a slot terminating a waveguide of short length coupled to the main feeding guide. On account of its great simplicity we have embarked first on the study of (ii) as shown in Figure 5.

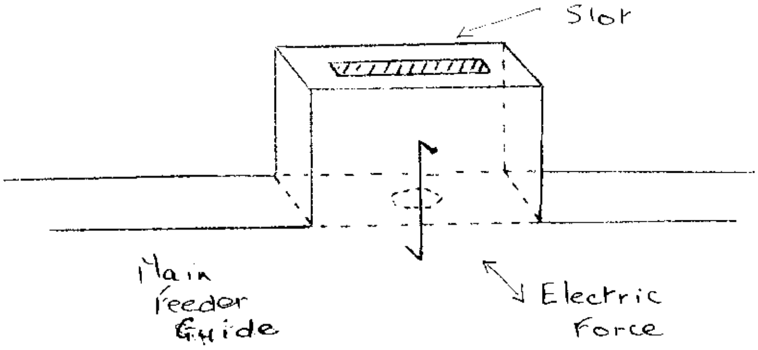

Fig. 5

II. CONCLUSIONS RE DIPOLE AND WAVEGUIDE FEED

Our measurements have brought into sharp focus the following points:-

1. The main difficulty to be overcome in the design of the dipole (or other radiating element) is to secure mechanical robustness and at the same time achieve at least a good approximation to the desired electrical performance. The feed should be as "flat" as possible so as to eliminate reactance at its source. The high resistance required for each feed point in a long array is to be secured by feeding from a place of weak electric field in the guide. Radiation in the unwanted polarisation is likely to be excessive from any exposed feeder probe: this spoils both the radiation pattern and makes the correct feeding of a long array difficult if not impossible.

2. A simple procedure has been found for controlling the equivalent shunt resistance and reactance due to the probe itself and for reversing the phase of alternate radiators without changing their aspect with respect to the outside of the guide. The requirements on the degree of transverse pattern symmetry are therefore not nearly so severe as when alternate radiators are reversed.

III. 'GABLING' OF THE ARRAY AND FREQUENCY SENSITIVITY OF ARRAYS

We have made calculations - Fourier analyses and theoretical radiation patterns - based on the method of Wolff (P.I.R.E. 1937) for the design of a 41 - 45 element array, and have considered the possibility of feeding the array at its centre as well as at its end. We have chosen the gabling function with the object of securing as narrow a beam as is possible without permitting side lobes exceeding 1.0% in energy. With

$.8\lambda$ spacing of the 45 elements we calculate that it should be possible to obtain a main beam of 2.0° with side lobes below the above figure. The figure of merit of the array is 1.23: it should be compared with data at present available on microwave arrays.

We suggest that in the design of microwave arrays too little attention has been paid to the effective use of the length of the array in assessing their performance. If α is the full width of the main beam at half-field strength and L is the length of the array, the number $\frac{\alpha L}{\lambda}$, which might be called the <u>figure of merit</u> of the array should be kept as small as consistent with the allowed size of side lobes. In this way one can easily judge whether or not the elements at the ends of the array will play their full part instead of contributing merely a small amount of energy for the purpose of suppressing side lobes. On the basis of optical principles they ought really to contribute to the sharpness of the main beam.

In long arrays the main factor limiting the range of frequency variation that can be tolerated in practice is the small permissible variation in phase between the ends of the array, in order to allow the array to be fed properly. The longer the array the more precisely must the frequency be fixed. For example in a 32-foot array of 120 cophased elements spaced $0.8\lambda = \lambda_g/2$ at $\lambda = 10$ cm, if the variation in phase between the ends of the array is to be kept less than 45°, the frequency must not vary by more than 1 part in 8 x 60 = 480. The corresponding variation in the direction of the main beam will be about 1/12°, which is of no practical significance.

E.W. Guptill
F.R. Terroux
W.H. Watson

Ottawa
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